Role of Indocyanine Green Videoangiography in Identification of Donor and Recipient Arteries in Cerebral Bypass Surgery

Esposito, Giuseppe ; Dias, Sandra ; Burkhardt, Jan-Karl ; Bozinov, Oliver ; Regli, Luca

Abstract: The identification and preparation of a very good quality donor artery is a crucial step in every superficial temporal artery to middle cerebral artery (STA-MCA) bypass.For flow-preservation bypass performed for trapping of complex MCA aneurysms, the key element is the correct target of the recipient artery. When a cortical recipient artery (M4 segment of the MCA) is selected, this vessel must be a terminal branch of the artery whose sacrifice is necessary for definitive aneurysmal treatment.In this chapter we report on two techniques for (1) intraoperative mapping and preparation of good quality STA branch as the donor artery for STA-MCA bypass (mostly in the case the frontal branch of the STA needs to be used) and (2) selective identification of the correct superficial (M4 cortical) "recipient" artery in flow-preservation STA-MCA bypass performed for managing complex MCA aneurysms.Both techniques are based on the use of microscope-integrated indocyanine green videoangiography (ICG-VA), an intraoperative tool allowing observation and real-time assessment of blood flow in large and small vessels, with distinct evaluation of arterial, capillary, and venous phases.The two techniques contribute, respectively, to (1) reduce the risk of erroneous identification or injury of the donor artery in STA-MCA bypass procedures and (2) eliminate the risk of erroneous revascularization of a non-involved arterial territory in flow-preservation bypass surgery for managing complex MCA aneurysms.

DOI: https://doi.org/10.1007/978-3-319-73739-3_12

Originally published at:
Esposito, Giuseppe; Dias, Sandra; Burkhardt, Jan-Karl; Bozinov, Oliver; Regli, Luca (2018). Role of Indocyanine Green Videoangiography in Identification of Donor and Recipient Arteries in Cerebral Bypass Surgery. In: Esposito, Giuseppe; Regli, Luca; Kaku, Yasuhiko; Tsukahara, Tetsuya. Trends in the Management of Cerebrovascular Diseases. Cham: Springer, 85-89.
DOI: https://doi.org/10.1007/978-3-319-73739-3_12

Title: Role of Indocyanine green video-angiography for identification of donor and recipient artery in cerebral bypass surgery

Giuseppe Esposito, Sandra Dias, Jan Burkhardt, Oliver Bozinov, Luca Regli

Department of Neurosurgery, University Hospital Zurich, University of Zurich, Zurich, Switzerland

Corresponding author:

Giuseppe Esposito, MD, PhD
Department of Neurosurgery
University Hospital Zurich
Frauenklinikstrasse 10 - CH-8091 Zürich
Telefon: +41-44-2558656
TeleFax: +41-44-2554387
Email: giuseppe.esposito@usz.ch

Abstract:

The identification and preparation of a very good quality donor artery is a crucial step of every superficial temporal artery to middle cerebral artery (STA-MCA) bypass.

For flow-preservation bypass performed for trapping of complex MCA aneurysms, key element is the correct target of the recipient artery. When a cortical recipient artery (M4 segment of the MCA) is selected, this vessel must be a terminal branch of the artery whose sacrifice is necessary for definitive aneurysmal treatment.

In this article we report on two techniques for: 1) intraoperative mapping and preparation of good quality STA branch as donor artery for STA-MCA bypass (mostly in the case the frontal branch of the STA needs to be used); 2) selective identification of the correct superficial (M4 cortical) "recipient" artery in flow-preservation STA-MCA bypass performed for managing complex MCA aneurysms.

Both the techniques are based on the use of microscope-integrated Indocyanine green videoangiography (ICG-VA), an intraoperative tool allowing observation and real-time assessment of blood flow in large and small vessels, with distinct evaluation of arterial, capillary and venous phases.

The two techniques contribute respectively to: 1) reduce the risk of erroneous identification or injury of the donor artery in STA-MCA bypass procedures; 2)

eliminate the risk of erroneous revascularization of a non-involved arterial territory in flow-preservation bypass surgery for managing complex MCA aneurysms.

Key Words: cerebral bypass; donor artery; extra-intracranial bypass; flow-preservation bypass; Indocyanine green videoangiography - ICGVA; neurosurgery; recipient artery; selective revascularization.

Abbreviation

EC-IC – Extra.to-intracranial; DSA – Digital subtraction angiography; ICGVA - Indocyanine green videoangiography; MCA – Middle cerebral artery; STA – superficial temporal artery – STA-MCA: superficial temporal artery to middle cerebral artery.

Introduction

A crucial step of every STA-MCA bypass procedure (both flow-preservation and flow-augmentation) is the reliable identification and safe dissection of the donor artery, namely the superficial temporal artery (STA).[3]

For flow-preservation bypass performed for trapping complex aneurysms of the middle cerebral artery (MCA), a key element is the correct target of the recipient artery. [2, 4-8, 10] The bypass must supply adequate blood flow to the brain perfused by the trapped vessel. [1, 2, 4, 5, 7-9, 14] When a cortical recipient artery (M4 segment of the MCA) is selected, this vessel must be a terminal branch of the artery whose sacrifice is necessary for definitive aneurysm treatment. [4, 7]

Microscope-integrated Indocyanine green videoangiography (ICG-VA) allows intraoperative and real-time assessment of blood flow in large and small vessels, with distinct evaluation of arterial, capillary, and venous phases. [12, 13]

With this work, we present the way we use ICGVA for: 1) intraoperative mapping and preparation of good quality STA branch as donor artery for STA-MCA bypass (mostly in the case the frontal branch of the STA needs to be used); 2) selective identification of the correct superficial (M4 cortical) “recipient” artery in flow-preservation STA-MCA bypass performed for managing complex MCA aneurysms. These two techniques have been separately reported by us in the last years.[3, 4]

ICGVA-assisted identification of bypass donor artery

The STA divides into two branches: an anterior frontal and a posterior parietal.[11] If only the parietal branch needs to be prepared, a linear incision above this parietal branch allows its dissection under the microscope. [3] In the case the frontal branch of the STA has to be used (for instances in case of absent/hypoplasic parietal branch as well as for double barrel STA-MCA bypass), the surgeon usually dissects the frontal branch from the underside of a fronto-temporal scalp flap. [3] This dissection can however be difficult because of: additional skin retraction required to expose the artery; dissection through the fat plane; variability in the anatomy of the STA-branches. [3]

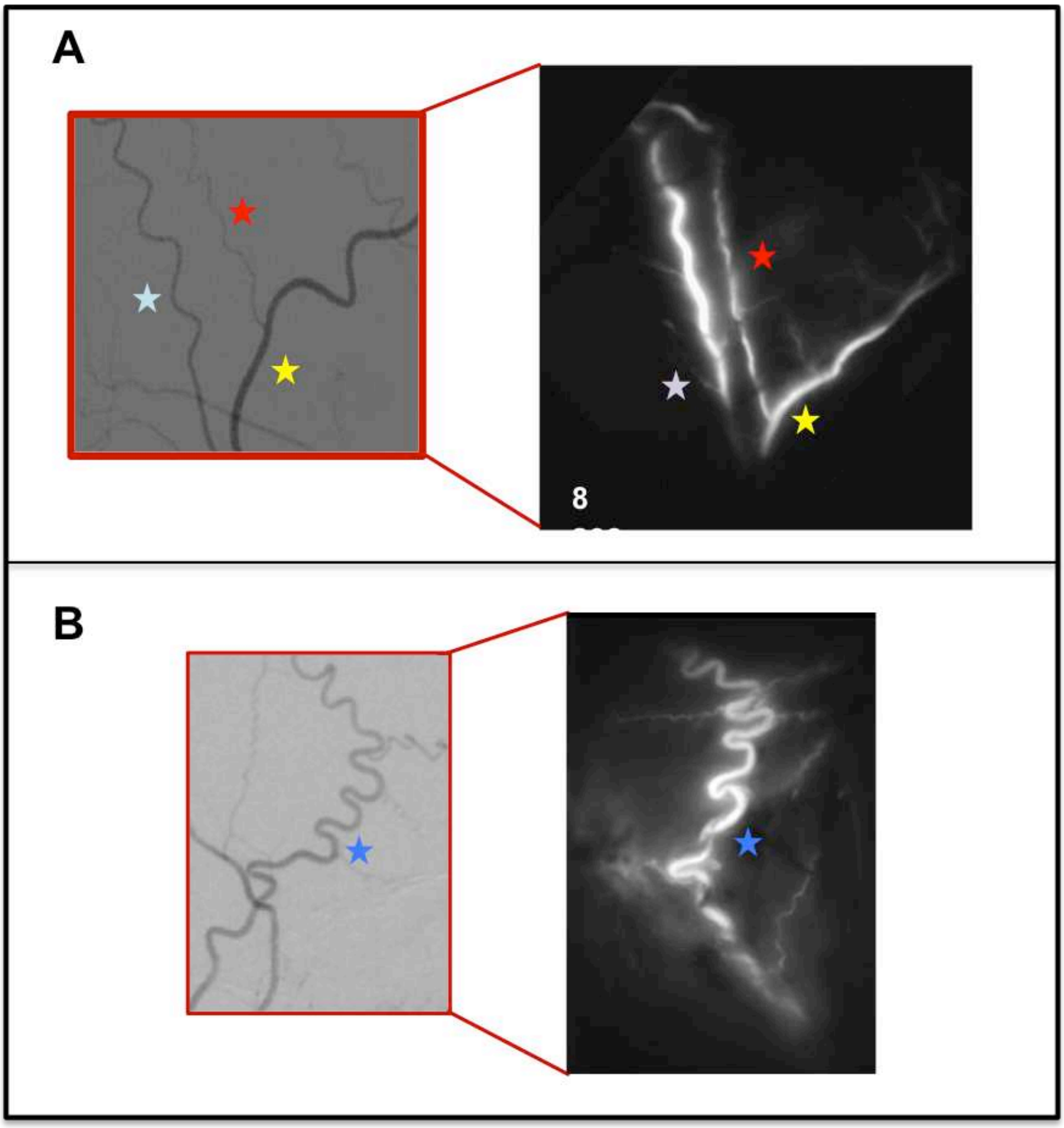
The ICGVA-assisted technique herein described allows intraoperative mapping and preparation of good quality STA branch as donor artery for STA-MCA bypass: the technique is useful mostly in the case the frontal branch of the STA needs to be dissected. [3]

This technique is based on the analysis of the difference in time of filling of scalp vessels illuminated via ICG-VA from the underside of a scalp flap. [3]

ICG-VA is performed using a commercially available surgical microscope (OPMI® Pentero™, The Carl Zeiss Co, Oberkochen, Germany). A standard dose of 25 mg of ICG is dissolved in 5 mL of water and injected into a central vein as a bolus. The underside of the fronto-temporal scalp flap is illuminated with near-infrared light and the anatomy of the visualized vasculature studied. ICG-VA videos are analysed on video screen and recorded for further analysis. [3]

ICG-VA allows to: visualize the the whole pattern of the STA at once before preparation (Figure 1A); differentiate the STA-branches running parallel (Figure 1A); precisely mapping the donor in case of serpiginous STA (Figure 1B); localize the bifurcation-points of the STA-branches (Figure 1A); precisely define the location of all the branching points in the late arterial phase (Figure 1A-B).

This technique results very effective for mapping and preparing very good quality donor artery.[3] It may reduce the risk of erroneous identification or injury of the donor artery, mainly in case of anatomical variations of the STA such as: changes in main bifurcation site (over or below the zygomatic arch), absence of bifurcation, hypoplasia or absence of one of the branch, double parietal branches, further bifurcation along the branches, and serpiginous course.[3] The presented technique is not intended to substitute the use intraoperative Doppler for identification of the STA branches, but rather as an alternative/complementary tool. [3]



A. On the left side, pre-operative DSA with selective injection of the left external carotid artery showing the frontal and parietal branches of the left STA. On the right side, ICG-VA demonstrating the course of the frontal (yellow star) and parietal (light blue star) branches of the STA from the underside of the left fronto-temporal scalp flap. ICG-VA differentiates the STA-branches running parallel (light blue and red stars) and shows (in the late arterial phase of the angiography, 8 sec) all the branching points of the STA. The red star indicates a subbranch of the frontal STA.

B. On the left side, pre-operative DSA with selective injection of the left external carotid artery demonstrating a serpiginous course of the frontal branch of the STA (blue star). On the right side, ICGVA shows the frontal branch has a serpiginous course and all the branching points of the STA. (*Modified from Esposito et al, Acta Neurochir, 2016)[3]*

ICGVA-assisted identification of bypass recipient artery

For flow-preservation bypass performed for trapping complex MCA aneurysms, the selection of the correct recipient artery is an essential step. When microsurgical dissection of the Sylvian fissure and of the aneurysmal angioanatomy is safe, the selection of a M2-M3 segment of MCA as recipient is a valid choice. When microsurgical dissection is considered more risky or when avoiding a deep site for the anastomosis is preferred, a cortical recipient artery (M4 segment of MCA) can be selected. [4, 7] It is essential that this recipient artery represents indeed a distal branch of the artery whose sacrifice is needed to treat the aneurysms (by aneurysmal trapping). Because each M2 segment feeds several cortical (M4) arteries, the risk of revascularization into a wrong territory exists. This despite the use of anatomical landmarks, preoperative neuroimaging, neuronavigation and stereotactic techniques) [4, 7]

The ICGVA-assisted technique herein presented allows selective identification of the correct superficial (M4 cortical) “recipient” artery in flow-preservation STA-MCA bypass performed for managing complex MCA aneurysms by the use of trapping strategies. This way it eliminates the risk of erroneous revascularization of a non-involved arterial territory.

The possibility to select a superficial recipient (M4) artery makes the bypass easier and less invasive. Furthermore, tolerance to ischemia is better during temporary occlusion of a cortical M4 artery as compared to occlusion of a more proximal M2 or M3 branch.[4, 7]

ICG-VA is performed as described above. This time however the cortex around the sylvian fissure is illuminated with near-infrared light: the difference in the direction and in the time of filling of M4 cortical arteries is analyzed. [4] ICGVA allows in fact assessing a delayed or reversed arterial filling, as well as delayed capillary/venous filling.[4, 7, 13]

As schematized in the flow-chart in Figure 2, a delay in cortical M4 arteries filling may be seen in two different circumstances. The first is *primarily* on a baseline ICG-VA without any temporary occlusion of arteries. Such a delay can be caused by any increased resistence to flow (i.e.: stenosis/occlusion of an aneurysmal branch, intra-aneurysmatic turbulent flow, serpiginous aneurysm). We define this as *primary* identification (Figure 2). [4] The second circumstance is the detection of delayed flow *secondarily,* after provocative temporary occlusion of an artery. This implies temporary test-occlusion (via application of a temporary clip) of any MCA branch that may need to be occluded for final aneurysm treatment. We define this as *secondary* identification [4] (Figures 2-3). These two conditions are defined *primary and secondary identification* respectively (Figure 2). [4]

Any *primary* or *secondary* delayed fluorescence of M4 branches (fluorescence is visualized during the capillary/venous phases of ICG-VA) defines a cortical area around the sylvian fissure with delayed vascular filling. The most suitable cortical artery within this cortical area can be targeted as bypass recipient artery (Figures 2-3). [4]

ICG-VA can be repeated as many times as needed: important is to remain within the daily dose limit of ICG (5 mg/kg) and to wait at least 10 min between two consecutive intravenous ICG injections (to allow washout of the previous administered ICG).

The possibility to repeat ICGVA enabled us to study the cortical filling before (*baseline ICG-VA*), as well as during temporary occlusion of MCA branches (*provocative ICG-VA*), and after bypass construction and aneurysm treatment (*final ICG-VA*) (Figure 2). [4]

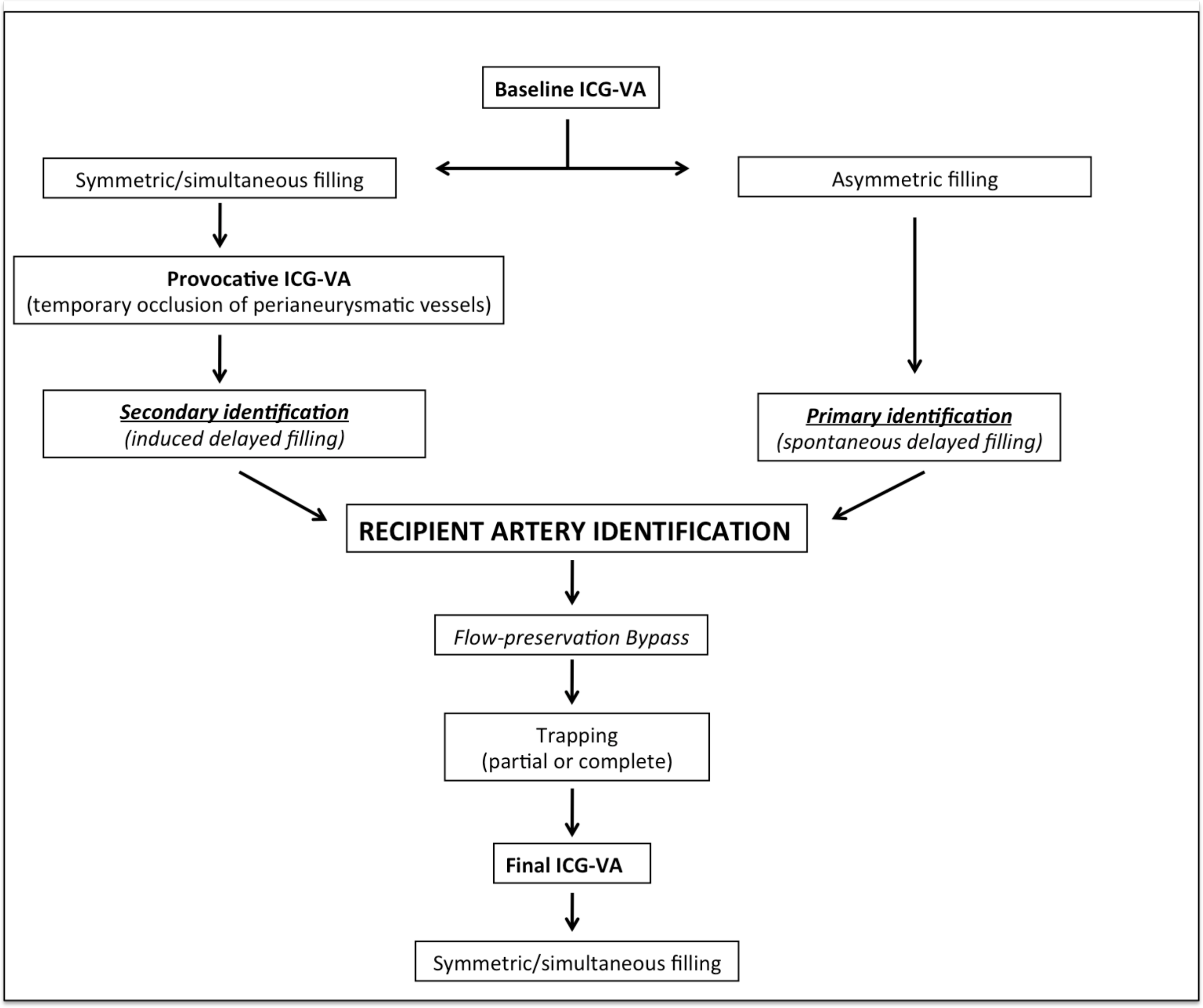


Figure 2. Flow chart illustrating the strategy in serial ICG-VAs performed for selective-targeted identification of the cortical recipient artery in flow-preservation EC-IC bypass surgery. *(Modified from: Esposito et al, Neurosurgery, 2012)[4]*

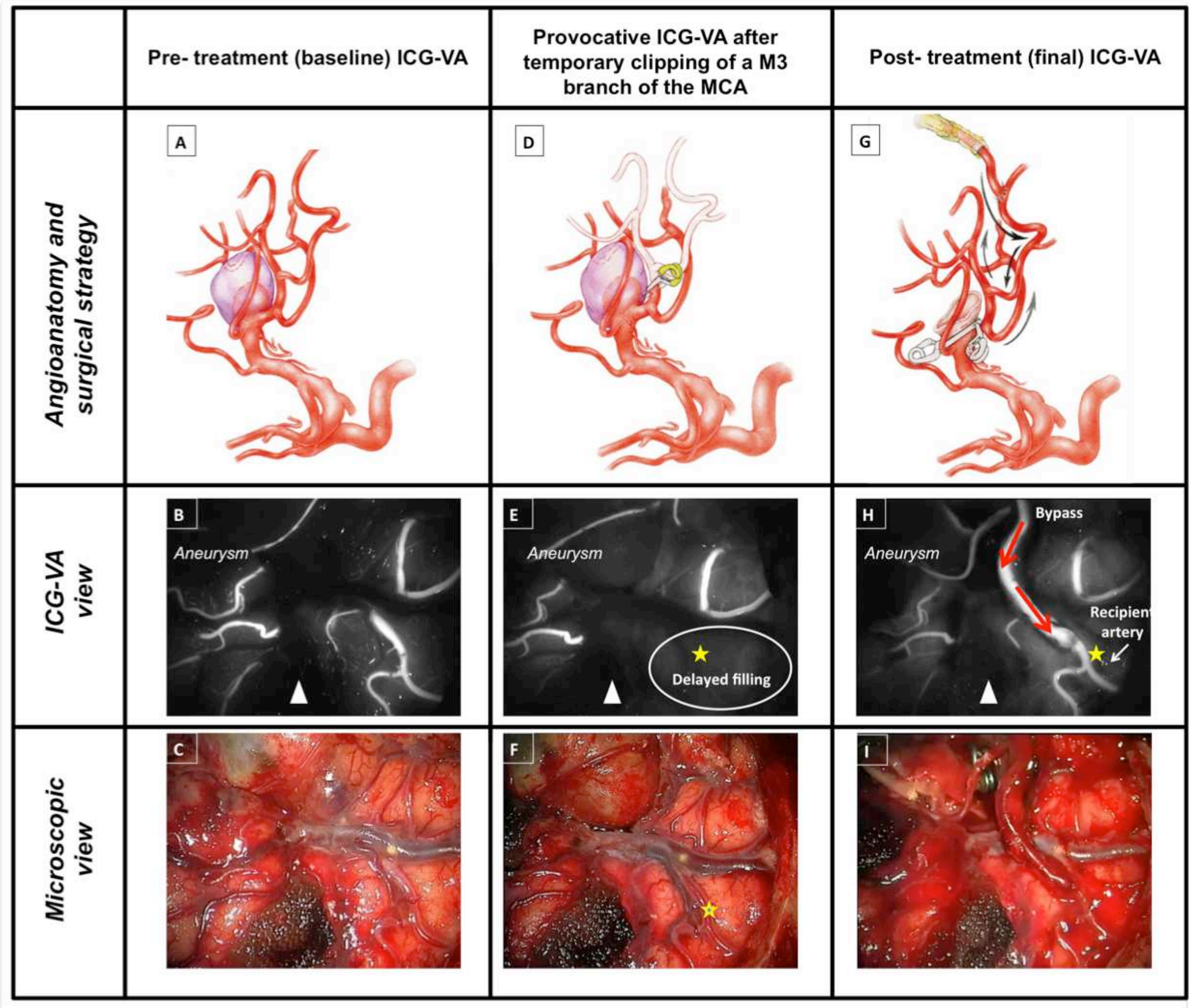


Figure 3 (patient 2) – secondary identification

A. Drawing: partially thrombosed aneuryms of the right M1 bifurcation.
B. Baseline ICG-VA: simultaneous filling of all the exposed cortical (M4) arteries.
C. Intraoperative microscopic view of the ICG-VA field shown in Figure 3B.
D. Drawing: a temporary clip on the M3 segment of the MCA is placed to perform a provocative ICG-VA.
E. Provocative ICG-VA: an area presenting a delayed filling is evident. A suitable artery in this territory is then selected as recipient (see yellow asterisk.
F. Intra-operative microscopic view of the ICG-VA field shown in Figure 2E (the yellow asterisk represents the recipient artery).
G. Drawing: final aneurysm treatment: trapping + flow-prreservation bypass.
H. Final (post-bypass) ICG-VA: the bypass is patent and the cortex takes fluorescence simultaneously.
I. Intra-operative microscopic view of the ICG-VA field shown in Figure 2H.

*White triangles indicate surgery-related decreased fluorescence on ICG-VA. DSA: digital subtraction angiography; ICG-VA: indocyanine green videoangiography.

(Modified from: Esposito et al, Neurosurgery, 2012 and Esposito et al, Neurosurgery, 2014)

CONCLUSIONS

The two reported ICGVA-assisted techniques allow: 1) mapping and preparation of very good quality donor vessel in STA-MCA bypass (mostly if the frontal branch of the STA has to be used); 2) reliable and accurate identification of the cortical recipient artery and elimination of the risk of erroneous revascularization of a non-involved arterial territory in flow-preservation bypass surgery performed for managing complex MCA aneurysms.

References

1. Burkhardt JK, Esposito G, Fierstra J, Bozinov O, Regli L (2016) Emergency Non-occlusive High Capacity Bypass Surgery for Ruptured Giant Internal Carotid Artery Aneurysms. Acta Neurochir Suppl 123:77-81
2. Esposito G, Amin-Hanjani S, Regli L (2016) Role of and Indications for Bypass Surgery After Carotid Occlusion Surgery Study (COSS)? Stroke 47:282-290
3. Esposito G, Burkhardt JK, Bozinov O, Regli L (2016) Indocyanine green videoangiography for the identification of superficial temporal artery branches in EC-IC bypass surgery. Acta Neurochir (Wien) 158:565-570
4. Esposito G, Durand A, Van Doormaal T, Regli L (2012) Selective-targeted extra-intracranial bypass surgery in complex middle cerebral artery aneurysms: correctly identifying the recipient artery using indocyanine green videoangiography. Neurosurgery 71:ons274-284; discussion ons284-275
5. Esposito G, Fierstra J, Regli L (2016) Distal outflow occlusion with bypass revascularization: last resort measure in managing complex MCA and PICA aneurysms. Acta Neurochir (Wien) 158:1523-1531
6. Esposito G, Fierstra J, Regli L (2016) Partial Trapping Strategies for Managing Complex Intracranial Aneurysms. Acta Neurochir Suppl 123:73-75
7. Esposito G, Regli L (2014) Selective Targeted Cerebral Revascularization via Microscope Integrated Indocyanine Green Videoangiography Technology. Acta Neurochir Suppl 119:59-64
8. Esposito G, Regli L (2014) Surgical decision-making for managing complex intracranial aneurysms. Acta Neurochir Suppl 119:3-11
9. Jafar JJ, Russell SM, Woo HH (2002) Treatment of giant intracranial aneurysms with saphenous vein extracranial-to-intracranial bypass grafting: indications, operative technique, and results in 29 patients. Neurosurgery 51:138-144; discussion 144-136
10. Kronenburg A, Esposito G, Fierstra J, Braun KP, Regli L (2014) Combined Bypass Technique for Contemporary Revascularization of Unilateral MCA and Bilateral Frontal Territories in Moyamoya Vasculopathy. Acta Neurochir Suppl 119:65-70
11. Pinar YA, Govsa F (2006) Anatomy of the superficial temporal artery and its branches: its importance for surgery. Surg Radiol Anat 28:248-253
12. Raabe A, Beck J, Gerlach R, Zimmermann M, Seifert V (2003) Near-infrared indocyanine green video angiography: a new method for intraoperative assessment of vascular flow. Neurosurgery 52:132-139; discussion 139

13. Scerrati A, Della Pepa GM, Conforti G, Sabatino G, Puca A, Albanese A, Maira G, Marchese E, Esposito G (2014) Indocyanine green video-angiography in neurosurgery: a glance beyond vascular applications. Clin Neurol Neurosurg 124:106-113
14. Sekhar LN, Natarajan SK, Ellenbogen RG, Ghodke B (2008) Cerebral revascularization for ischemia, aneurysms, and cranial base tumors. Neurosurgery 62:1373-1408; discussion 1408-1310